EVA Technology Collaboration Workshop

ISS EVA – State of the Art

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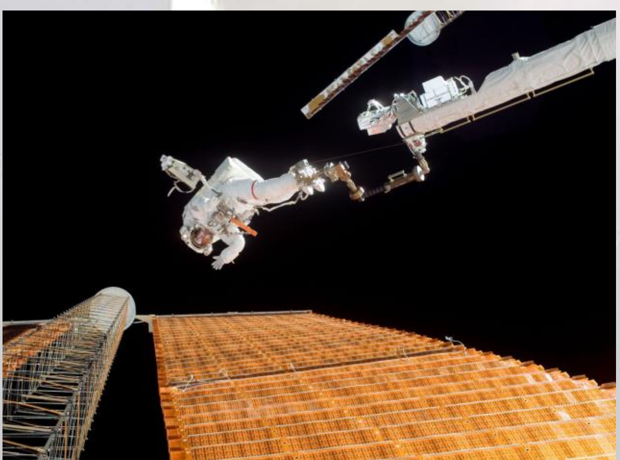
ISS / EMU Background

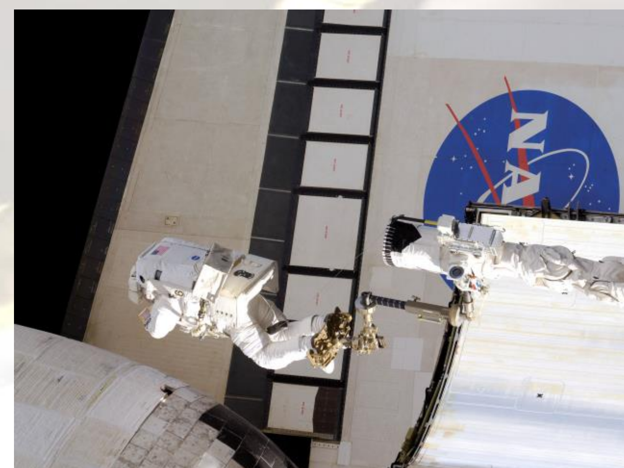
- ISS EVA Operations
  - ISS operational life has been baselined to 2024
  - Per ISS Program direction, the EVA Office is planning continued EVA support thru at least 2024 <u>using the EMU</u>, including strategic planning for use of EMU to 2028
- ISS operations is a significant learning opportunity for EVA
  - Operation (Assembly and Maintenance of ISS) with the EMU and associated EVA tools provide a constant assessment of the state of the art
- To support high fidelity demonstration or nominal operations of advanced suit systems, only minor ISS modifications are anticipated
  - ISS Program has been very supportive in the study of interface accommodation changes for advanced EVA hardware

Implementation of advanced operational EVA capabilities on ISS is feasible, beneficial, and a tremendous opportunity for Exploration

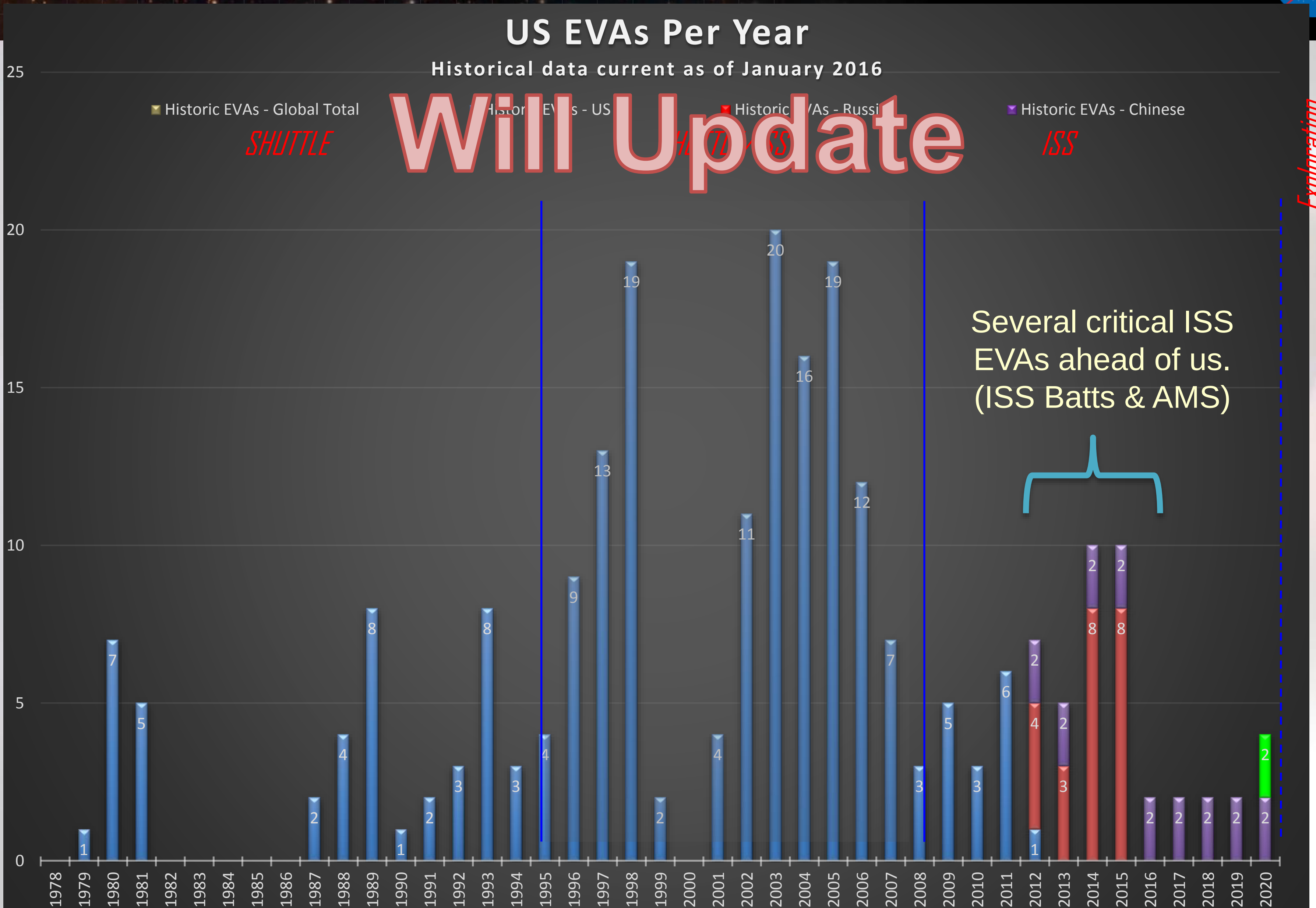
EVA Development Opportunity on ISS

- “Desirements” for future EVA systems test, evaluation and operation
  - Hardware validation: Demonstration and/or nominal operational use of advanced EVA systems will give us significantly more insight into real environmental performance and overall “wear and tear” (for micro-g)
  - Operational validation: ISS ops will lead to discovery and validation of new operational paradigms using latest technologies (e.g. high bandwidth comm to support procedure display)



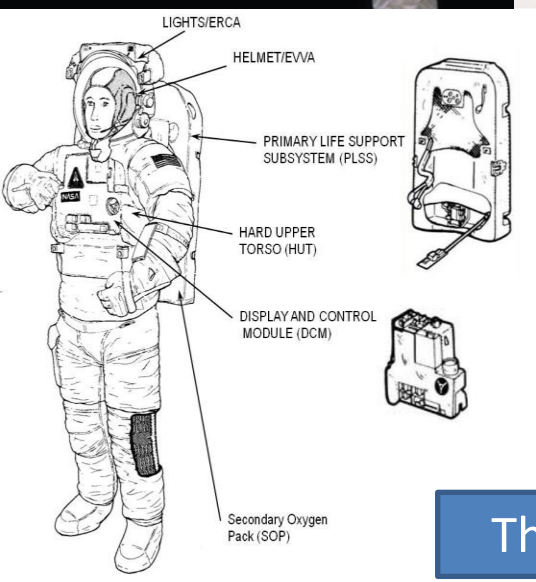


EVA Current Mission: ISS



Source (11/11/15): https://evahistoricalarchive.jsc.nasa.gov/ or http://www.nasa.gov/mission_pages/station/spacewalks

EMU History



- EMU Program hardware was originally designed to achieve a 15 year/100 mission life and certified for 2 weeks on orbit
  - EMU hardware deliveries began in 1978 (hardware began to go out of life in 1993) and it is in its 35^{th} year of operation
  - 11 Primary Life Support System flight units remain in inventory
- Assured EMU Availability (AEA) is a comprehensive program to evaluate the capability of EMU hardware to operate beyond its original 15-year/100 mission certification
  - Success-oriented program relies heavily on fleet-leader evaluations and certification endurance testing for the PLSS (although very successful to date, the program does rely on evaluations of a single unit)
  - The Space Suit Assembly or Pressure Garment typically procures new components after an 8-10 year life.
- Three significant changes to the EMU were required to support ISS
  - Orbital Replacement Unit (ORU) allows replacement of 4 items (PLSS, HUT, SOP, and DCM) individually without replacing an entire EMU on orbit
  - Enhanced SSA sizing redesign to allow on orbit suit sizing
  - Certified maintenance Interval incrementally extended (and waived to 7 years for specific serial numbers in 2016)

1982	1995	2000	2003	2007	2008
2 weeks	**0.5 Yr.**	**1 Yr.**	**2 Yrs.**	**3 Yrs.**	**6 Yrs.**
Shuttle Mission	25 EVAs over 180 Days	25 EVAs over 1 Year	25 EVAs over 2 Years	25 EVAs over 3 Years	25 EVAs over 6 Years

The EMU is not extensible to exploration missions beyond ISS

EVA Lessons Learned

- EMU Lessons Learned Papers
  - AIAA-2012-3411-926   AEMU to Shuttle EMU Comparison
  - ICES-2015-327 EMU FIAR History
  - 2005-01-3013 Lessons Learned Operating and Maintaining the EMU
    - Listing of all significant findings up through 2005
  - EMU shoulder injury tiger team report NASA Technical Report TM-2003–212058
    - Williams DR, Johnson BJ (2003) NASA Johnson Space Center, Houston, TX
  - Extravehicular mobility unit training and astronaut injuries
    - Strauss S, Krog RL, Feiveson AH (2005). Aviation, Space, and Environmental Medicine 76(5):469-74
  - Musculoskeletal injuries and minor trauma in space: incidence and injury mechanisms in U.S. astronauts.
    - Scheuring RA, Mathers CH, Jones JA, Wear ML (2009) Aviation, Space, and Environmental Medicine 80(2):117-24
- Mishap Reports
  - EVA-23 Water Intrusion Mishap Investigation Board Report
    - IRIS Case Number: S-2013-199-00005 (publicly available redacted version)
- EVA Reference Documentation
  - EMU Mini Databook (EAR Export Classification: ECCN [9E515.a])
  - EMU Requirements Evolution (Rev. B 2005 - EAR Export Classification: ECCN [9E515.a])
- EVA Operations Lessons Learned
  - Flight and Increment Lessons Center
    - EVA CCB lessons learned, Crew Consensus Reports, EMU Failure Tracking
    - https://nasa-ice.nasa.gov/portal/web/eva/flight-lessons-center (behind NASA firewall)

ISS EVA Lessons Learned

EVA History on ISS	Lesson Learned for Advanced EVA Development
EMU availability decrease due to issues with water intrusion into the vent loop	Separate the water and ventilation loops
EMU heat rejection (sublimator) sensitivity to water chemistry	More robust heat rejection systems and/or filter advancements (reduce sensitivity to operation in multiple spacecraft)
EMU has several single fault tolerant systems	Utilize advanced technologies to effectively add redundancy
EMU PLSS was not originally designed to be maintained on-orbit.	Utilize modular interfaces and packaging methods to enable R&R of critical components
EMU PLSS was not designed to be readily upgraded with newer components.	Utilize modular interfaces and packaging methods to enable removal and upgrade of components.
Long duration operation (years) on-orbit can and will reveal issues that can't be replicated on the ground.	Next generation system should be used in LEO for as long as possible (years) prior to first long duration mission.
Flight development and certification of batteries is hard!	Working with NESC to ensure best practices go into design and battery selection
Crew injury during training aggravated by suit design and suit fit	Remove as many injury mechanisms as possible. Ex. Rear entry, improved scye bearing placement, improved fit for wider anthro range